ECOSTRESS Update

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With support, encouragement and participation from many!

Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

Water stress threatens ecosystem productivity.

ECOSTRESS will provide critical insight into plant-water dynamics and how ecosystems change with climate via high spatiotemporal resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).

Science Objectives

- Identify critical thresholds of water use and water stress in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle
- Measure agricultural water consumptive use over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

When stomata close, CO2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.
**Mission**
- Class D $30M cost cap
- 31-months from project start to delivery
- JPL implementation and management
- 69-month project duration (Phase A-F)
- On ISS-JEMS Module
- 12-month Science Operations (Phase E)

The inclined, precessing ISS orbit enables ECOSTRESS to sample the diurnal cycle in critical regions across the globe at spatiotemporal scales missed by current instruments in Sun-synchronous polar and high-altitude geostationary orbits.

**Instrument**
- Leverages functionally-tested PHyTIR space-ready hardware developed under the NASA Instrument Incubator Program:
  - Spectral resolution: 5 bands in the thermal infrared window (8-12.5 μm) part of the electromagnetic spectrum
  - Noise equivalent delta temperature: ≤ 0.3 K
  - Spatial resolution: 38 m x 69 m
  - Swath width: 400 km @ 400 km altitude (51°)
- Well understood measurement and algorithms based on prior missions, such as ASTER, MODIS, and Landsat
**Science Team**

**Principal Investigator**
Simon Hook, JPL

**Co-Investigators**
Rick Allen, Univ. of Idaho
Martha Anderson, USDA
Joshua Fisher, JPL
Andrew French, USDA
Glynn Hulley, JPL
Eric Wood, Princeton Univ.

**Collaborators**
Christopher Hain, Univ. Maryland

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**Science Data Products**

<table>
<thead>
<tr>
<th>Level (L)</th>
<th>Data Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>L0</td>
<td>Raw data</td>
</tr>
<tr>
<td>L1</td>
<td>Radiometrically corrected Brightness Temperature</td>
</tr>
<tr>
<td>L2</td>
<td>Surface Temperature and Emissivity</td>
</tr>
<tr>
<td>L3</td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>L4</td>
<td>Water Use Efficiency, Evaporative Stress Index</td>
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</tbody>
</table>

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**Push-whisk System**

- **Focal Plane**
  - 5 Bands x 256 Pixels
  - ±25.5°, 57m nadir resolution, 6186 Pixels, 384 km, 183 msec

- **Scan Mirror**
  - 40.7°, 38 m nadir resolution, 256 Pixels, 1.29 sec

- **ISS Velocity Direction**

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**System Diagram**

- **Nadir 51° Field of View**
- **Scan Mirror**
- **M2 M1 Baffle**
- **Vacuum Window**
- **Fold Mirror**
- **FPA**
- **Spectral Filters**
- **Lyot Stop and 60K Baffle**
- **M3 Relay**
- **Yoke**
- **Vacuum Enclosure Cover**
Mission Concept

Radiometer Instrument

ECOSTRESS Payload

Dragon-Trunk Falcon-9 LV

Installation on JEM-EF

Science Data Processing and Archive

MOS and Ground and Space Network

Data Collection

EOL Payload disposal via Dragon Trunk re-entry
Current Events

- 05/05/16 Quarterly
- 04/27/16 PPBE
- 04/26/16 Ianson Visit
- 04/30/16 CDR Pre-briefs to Stover/Ianson
- 04/29/2016 DMC
- 04/26/16 Fracture Control Board review to Freilich
- 04/14/16 Post CDR Review to Freilich
- 03/30/16 CDR Pre-briefs to Stover/Ianson
- 03/29/2016 DMC
- 03/21/16 Post CDR SnapShot to Robinson
- 03/08-09/16 Project CDR
- 03/01/16 Radiometer I&T
- 02/09/16 CDR Readiness Assessment
- 02/10/16 ISS Interface CDR
- 02/09/16 Phase II Safety Review
- 01/27/16 POIWG
- 01/26/16 Payload I&T and ATLO Peer Review
- 01/25/16 V&V Peer Review
- 01/20/16 Firmware Peer Review
- 01/12/16 Radiometer Mechanical Peer Review
- 01/04/16 Phase II Safety Data Package due
- 01/03/16 View
- 12/17/15 Thermal Peer Review
- 12/16/15 Electronics Peer Review
- 12/15/15 Telecom Peer Review
- 12/14/15 Optics, Detector & Calibration Peer Review
- 12/10/15 Accommodation Confirmation Briefing to DPMC
- 12/07/15 Fracture Control Board Review 3
- 12/07/15 FSW Peer Review
- 12/04/15 MOS, GDS, and SDS Peer Review
- 12/02/15 Radiometer I&T Peer Review
- 12/02/15 Science Peer Review
- 11/18/15 Payload Enclosure Peer Review
- 11/16/15 Fracture Control Board review-2
- 11/11/15 November MMR
- 11/05/15 Science Team Meeting #2
- 10/29/15 Scan Mechanism Peer Review
- 10/23/15 KDP- G
- 10/20/15 Fracture Control Board Review-1
- 10/14/15 October MMR
- 10/05/15 DMC
- 09/16/15 September MMR
- 09/12/15 August MMR
- 07/28/15 PDR
- 07/23/15 JAXA Face to Face meeting
- 07/14/15 Phase I Safety Review
- 07/01/15 Science Peer Review
- 06/30/15 Telecom SS Peer Review
- 06/24/15 JAXA Technical Exchange Meeting
- 06/23/15 ISS Interface PDR
- 06/19/15 Thermal Peer Review
- 06/18/15 Optics and Detector Peer Review
- 06/17/15 June MMR
- 06/12/15 Scan mechanism Peer Review
- 06/15/15 Radiometer structure peer review
- 06/11/15 Enclosure tabletop review
- 06/10/15 Electronics Peer Review
- 06/10/15 MOS/GDS and SDS Peer Review
- 06/05/15 FSW Peer Review
- 05/27/15 I&T and ATLO Peer Review
- 05/26/15 Firmware Peer Review
- 05/21/15 Motor Control Peer Review
- 05/21/15 WAP Downselect
- 05/20/15 Wi-Fi Tabletop Review
- 05/13/15 May MMR
- 05/06/15 Heat Exchanger Design Review
- 04/30/15 Cold Panel Peer Review
- 04/16/15 Cryocooler-thermal analysis Tabletop
- 04/16/15 Signal Chain/Flex Peer Review
- 04/15/15 KDP-B
- 04/08/15 April MMR
- 03/25/15 Wi-ELWG at JSC
- 03/24/15 Safety TIM/phase 0 at JSC
- 03/17/15 JAXA Briefing
- 03/11/15 March MMR
- 03/05/15 Inheritance Review
- 02/10/15 SRR/MDR
- 01/14/15 January MMR
- 01/12/15 Baseline Walkthrough
- 12/14/14 ECOSTRESS Science Team Meeting
- 12/10/14 December MMR
- 11/19/14 November MMR
- 11/06/14 ISS Kickoff Meeting
- 11/04/14 ESSP/SMD Meeting
- 10/01/14 Authority To Proceed (ATP)
ECOSTRESS June 16 Monthly Status Report

Detailed Description: (for items identified as yellow or red)

None.
EM Cryocooler Installation
SAF High-Bay 2 Cleanroom, 6/1/2016
• Some facts and figures
  – Focused on water use and availability
  – Selected in EVI-2
  – Class D mission on ISS
  – Uses PHyTIR developed under ESTO IIP
  – Deliver in early 2017
  – Launch in mid 2018
  – Nominal mission lifetime 1 year
# L1 Science Requirements and Margins

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Science Requirement (from PLRA)</th>
<th>Current Best Estimate @ 400 km</th>
</tr>
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<tbody>
<tr>
<td>Ground Sample Distance (m)</td>
<td>≤ 100 x ≤100</td>
<td>68.5 x 38.5</td>
</tr>
<tr>
<td>Crosstrack x Downtrack at nadir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swath width (ISS nominal altitude range is 385 to 415 km)</td>
<td>≥ 360</td>
<td>402</td>
</tr>
<tr>
<td>Wavelength range (µm)</td>
<td>8-12.5</td>
<td>8-12.5</td>
</tr>
<tr>
<td>Number of bands</td>
<td>≥ 3</td>
<td>5 TIR + 1 SWIR</td>
</tr>
<tr>
<td>Radiometric accuracy (K @300K)</td>
<td>≤ 1</td>
<td>0.5</td>
</tr>
<tr>
<td>Radiometric precision (K @300K)</td>
<td>≤ 0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Dynamic Range (K)</td>
<td>270-335</td>
<td>200-500</td>
</tr>
<tr>
<td>Data collection</td>
<td>CONUS, twelve 1,000 x1,000km key climate biomes and twenty-five FLUXNET sites. On average 1 hour of science data per day.</td>
<td>1.5 hours per day of science data</td>
</tr>
</tbody>
</table>
# ECOSTRESS Science Data Products

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
<th>Initial Availability to NASA DAAC</th>
<th>Median Latency in Product Availability to NASA DAAC after Initial Delivery</th>
<th>NASA DAAC Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Raw collected telemetry</td>
<td>6 months after IOC</td>
<td>12 weeks</td>
<td>To be assigned by NASA SMD/ESD</td>
</tr>
<tr>
<td>Level 1</td>
<td>Calibrated Geolocated Radiances</td>
<td>6 months after IOC</td>
<td>12 weeks</td>
<td>To be assigned by NASA SMD/ESD</td>
</tr>
<tr>
<td>Level 2</td>
<td>Surface temperature and emissivity</td>
<td>6 months after Level 1 data products are available</td>
<td>12 weeks</td>
<td>To be assigned by NASA SMD/ESD</td>
</tr>
<tr>
<td>Level 3</td>
<td>Evapotranspiration</td>
<td>2 months after Level 2 data products are available</td>
<td>12 weeks</td>
<td>To be assigned by NASA SMD/ESD</td>
</tr>
<tr>
<td>Level 4</td>
<td>Water use efficiency and evaporative stress index</td>
<td>2 months after Level 3 data products are available</td>
<td>12 weeks</td>
<td>To be assigned by NASA SMD/ESD</td>
</tr>
</tbody>
</table>
Calibration and Validation

- On-board blackbodies
- Vicarious calibration sites
- Validation sites (FLUXNET)

Lake Tahoe
Russell Ranch
Tonzi Ranch (23 m tower)
Using JPL Airborne Instruments for Precursor Studies:

HyTES Acquisition: July 9, 2014
Summary

- ECOSTRESS is possible because of the development of the PHyTIR instrument for HyspIRI-TIR supported by ESTO

- ECOSTRESS will address a subset of the science associated with HyspIRI

- The ECOSTRESS mission will help answer three key science questions:
  - How is the terrestrial biosphere responding to changes in water availability?
  - How do changes in diurnal vegetation water stress impact the global carbon cycle?
  - Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?

- ECOSTRESS has a clearly defined set of data products and mature algorithms

- Opportunity for combined HyspIRI-like datasets using the European EnMAP and ECOSTRESS with GEDI for structure

ECOSTRESS will launch in 2018 and provide highest spatial resolution thermal infrared data ever from the International Space Station. HyspIRI is planned for the 2023+ timeframe
Movie Time
Q1. How is the terrestrial biosphere responding to changes in water availability?

Uncertainty in our knowledge of carbon response is directly dependent on water response uncertainty and how plants use water under drying conditions.

Red areas (“hotspots”) are where global models disagree on water use efficiency (WUE) based biome changes with climate change. ECOSTRESS will reduce this uncertainty with measurements for WUE (GPP/ET).
Q2. How do changes in diurnal vegetation water stress impact the global carbon cycle?

ECOSTRESS acquires numerous samples throughout the day over 1 year (at 50° latitude shown, for example).

ECOSTRESS’s diurnal sampling measures the shape of the daily ET cycle. The afternoon decline in ET is related to water stress (clear day).

I: Xylem refilling after initial water release.
II: ET at maximum/potential rate in the morning.
III: Stomata shut down water flux in the afternoon.
IV: ET resumes at maximum/potential in early evening when demand is reduced.
Q3. Can agricultural vulnerability be reduced through advanced monitoring of agricultural water consumptive use and improved drought estimation?

ECOSTRESS’s spatial resolution will distinguish fine-scale landscape heterogeneity such as agricultural systems (top) and riparian corridors (bottom) similar to Landsat (left), whereas MODIS (right) does not.

Probability of producing valid ET estimates when satellite revisit time is 16 days (lower-right inset) vs. 4 days

ECOSTRESS’s temporal resolution provides a 9-fold decrease in ET error relative to Landsat.
HyTES Acquisition: July 9, 2014

Irrigated July 7-8:
- Organic Tomato
  - Mean LST = 309 K
- Conventional Tomato
  - Mean LST = 306 K

Irrigated July 2-3:
- Organic Corn
  - Mean LST = 304 K
- Conventional Corn
  - Mean LST = 303 K
- Alfalfa
  - Mean LST = 301.5 K